# Safeguarding California: Preparing for Climate Risks

*an update to the*
*2009 California Climate Adaptation Strategy*

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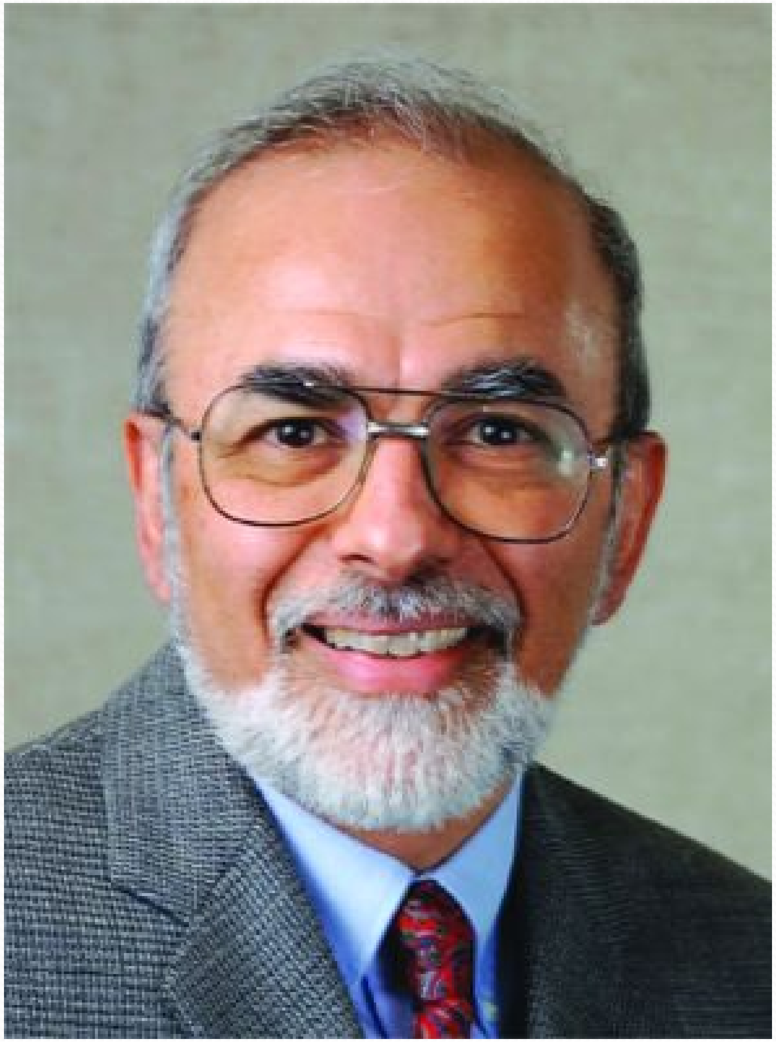
Public Workshop & Listening Session

CALIFORNIA natural resources AGENCY



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**Lawrence Berkeley National Laboratory**

# ESTIMATING RISK TO CALIFORNIA ENERGY INFRASTRUCTURE FROM PROJECTED CLIMATE CHANGE


## Jayant Sathaye

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**Session:**

**Safeguarding California: Preparing for Climate Risks**

**Truckee, CA**

**11 October 2013**

# Presentation Outline

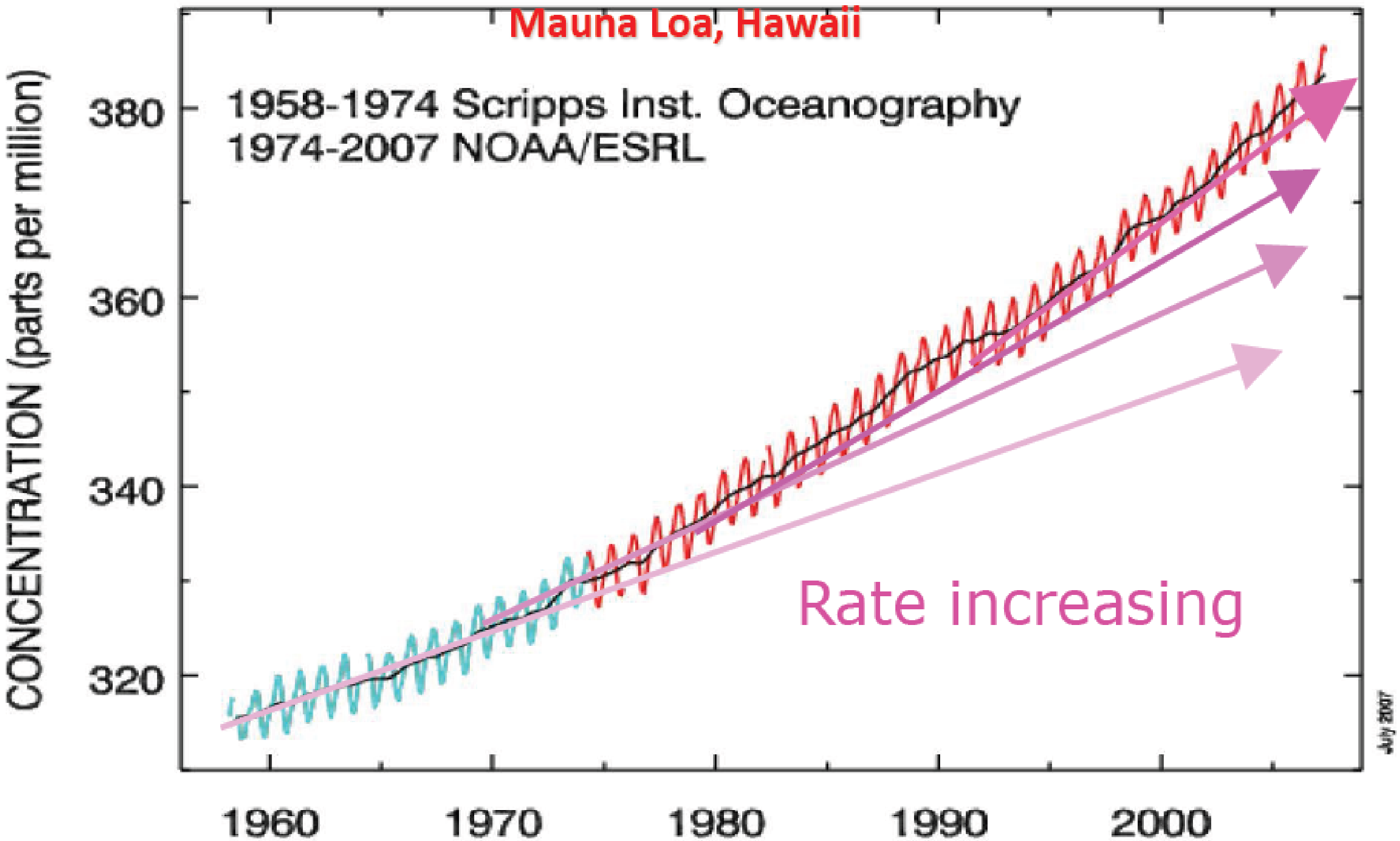
I. Context

II. Selected Review of International Impact Analyses

III. U.S. Case Study: California

IV. Lessons Learned

# Increasing Atmospheric $CO_2$



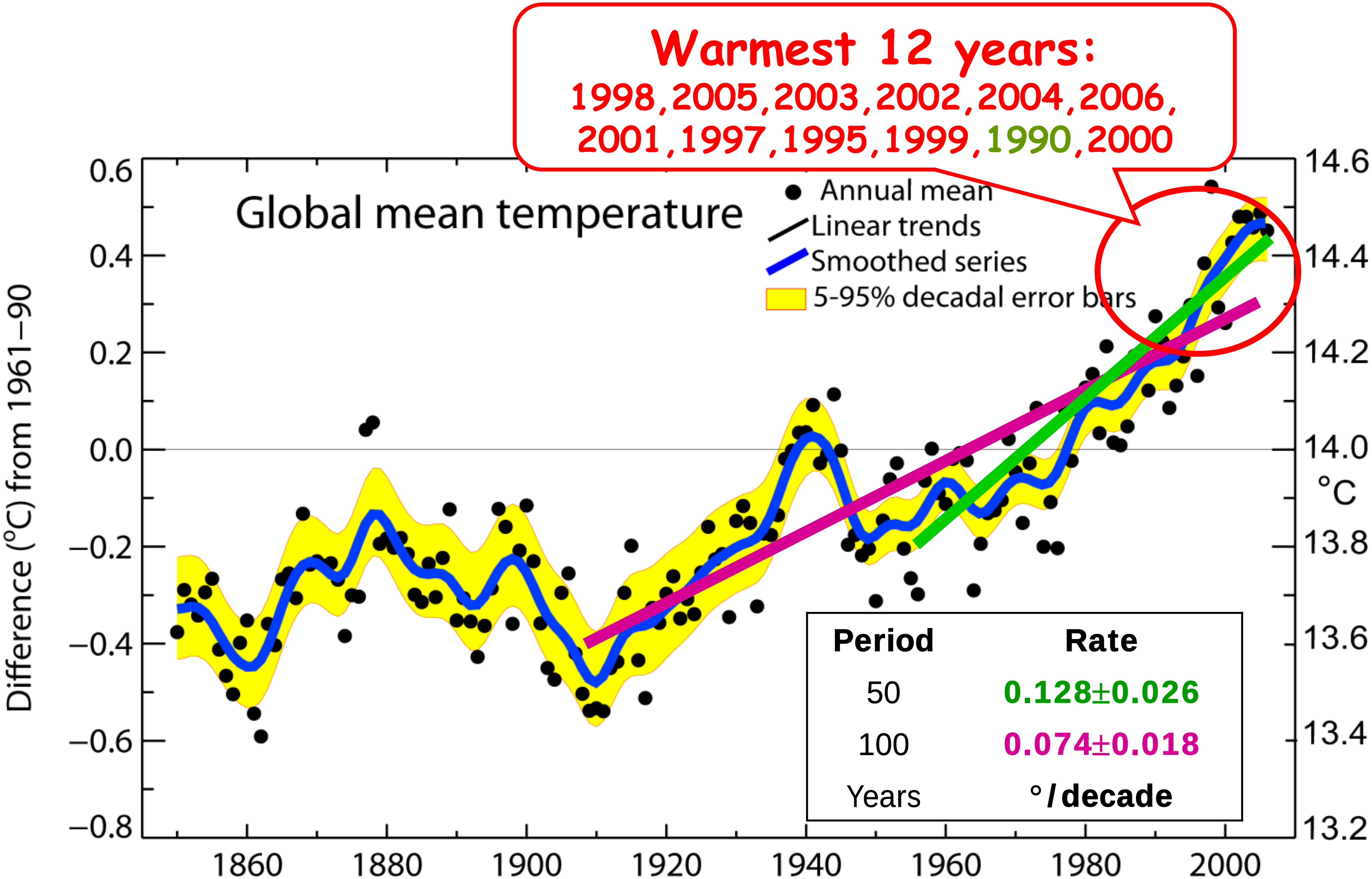

Data from Climate Monitoring and Diagnostics Lab., NOAA. Data prior to 1974 from C. Keeling, Scripps Inst. Oceanogr.

Fr: K Trenbreth, Climate Analysis Section, NCAR IPCC Lead Author



*Preliminary Results: Do not cite or reference.*

# Global Mean Temperatures are Rising Faster Over Time.




| Period | Rate |
|---|---|
| 50 | 0.128±0.026 |
| 100 | 0.074±0.018 |
| Years | ° / decade |

Source: IPCC

*Preliminary Results: Do not cite or reference.*

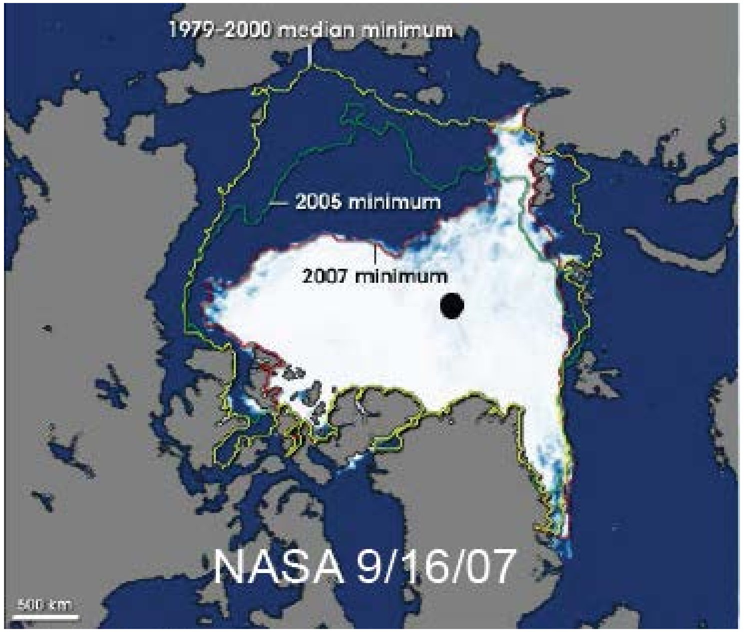
# Evidence for Global Warming is Unequivocal

**Since 1970, Rise in:**

- Global surface temperatures
- Tropospheric temperatures
- Global sea surface temperatures (SSTs), ocean temperatures, global sea level
- Water vapor
- Rainfall intensity
- Precipitation extratropics
- Hurricane intensity
- Drought
- Extreme high temperatures
- Heat waves
- Ocean acidity

**Decrease in:**

- NH Snow extent
- Arctic sea ice
- Glaciers
- Cold temperatures



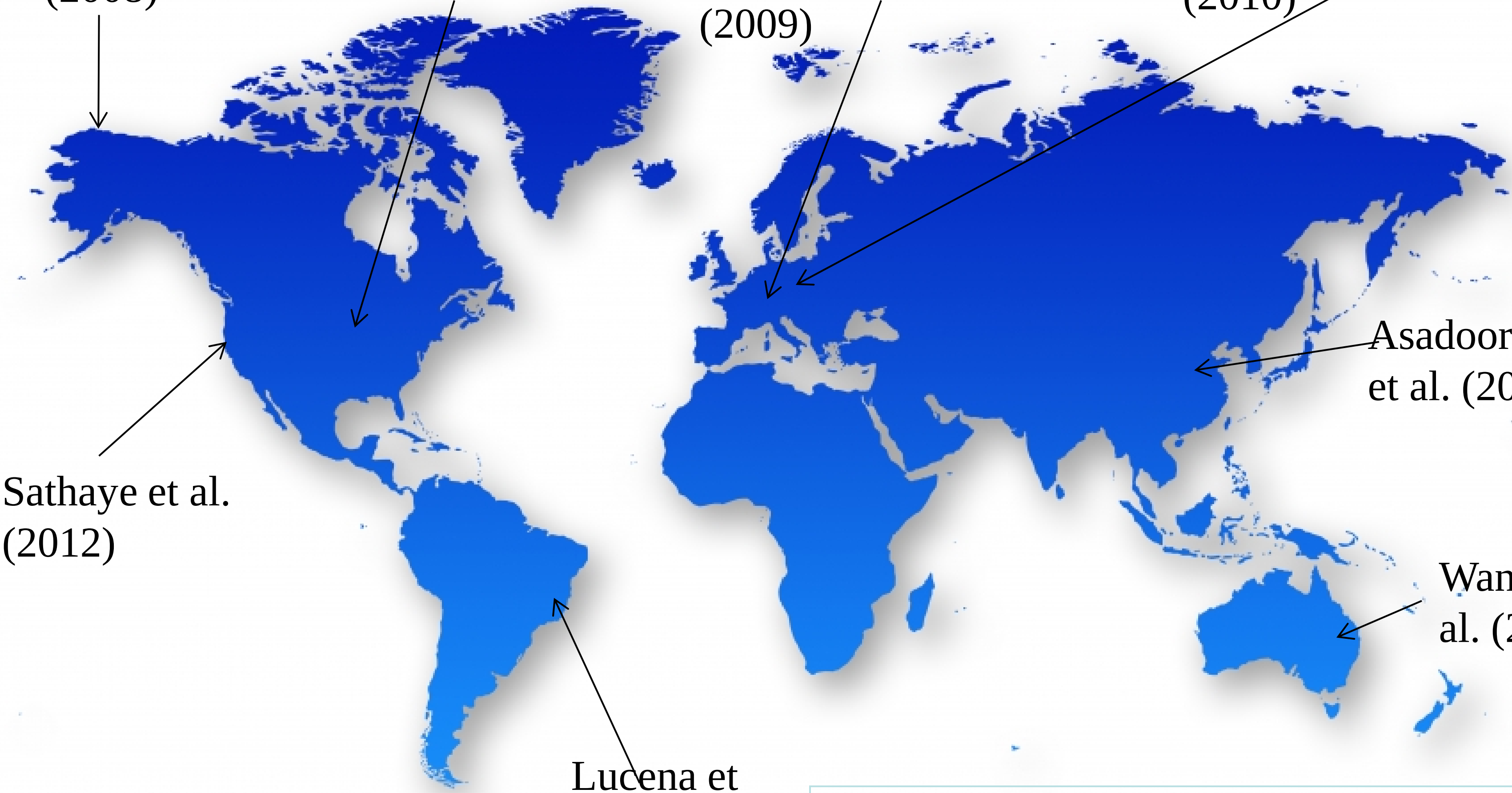

Fr: K Trenbreth, Climate Analysis Section, NCAR IPCC Lead Author

Source: John Spengler's presentation



*Preliminary Results: Do not cite or reference.*

# Selected Research List: Global, National and Local



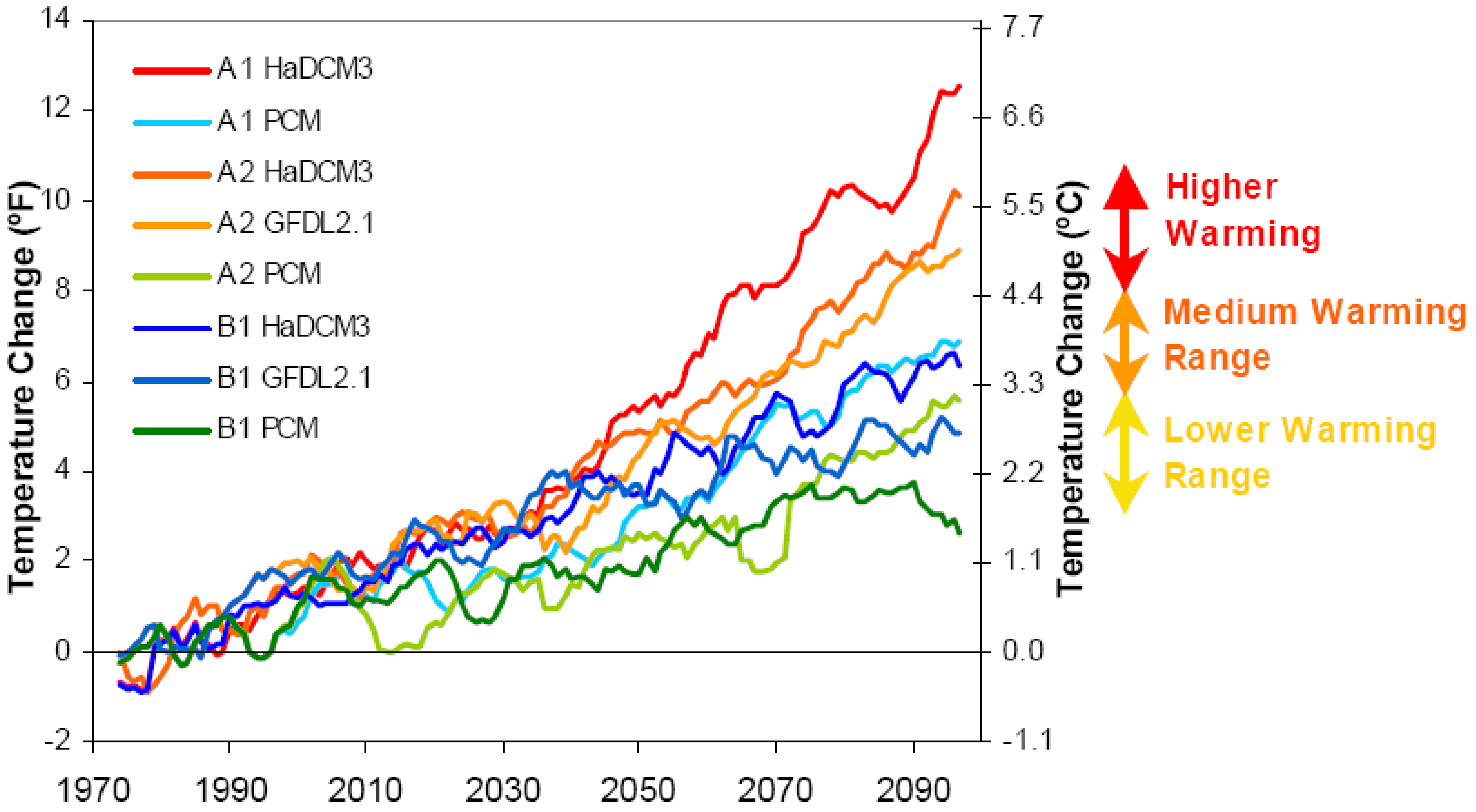

GLOBAL:

- Vergara et al./World Bank (in progress)
- Petrick et al. (2010)
- Wilbanks et al./IPCC-AR4 (2007)



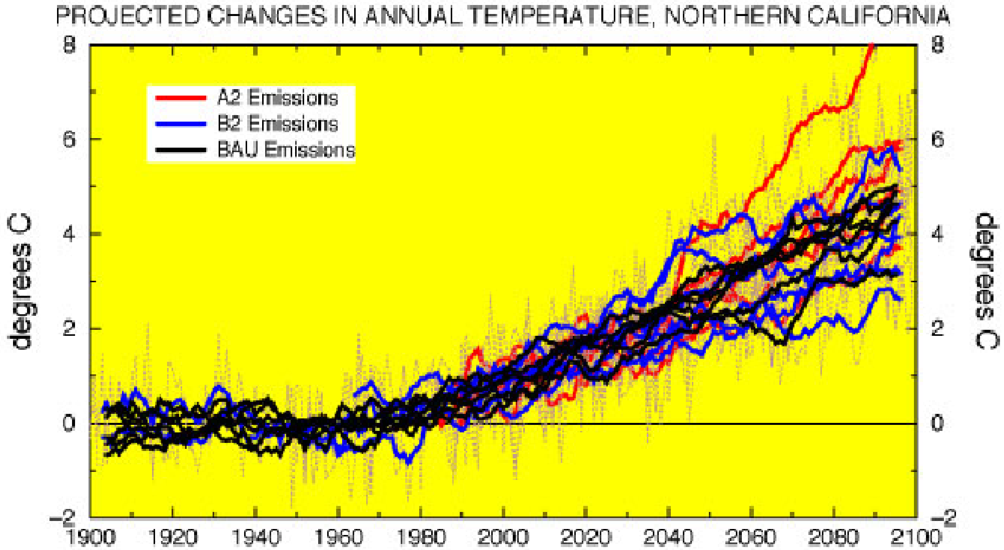
*Preliminary Results: Do not cite or reference.*

# Temperatures in California are Predicted to Rise Significantly

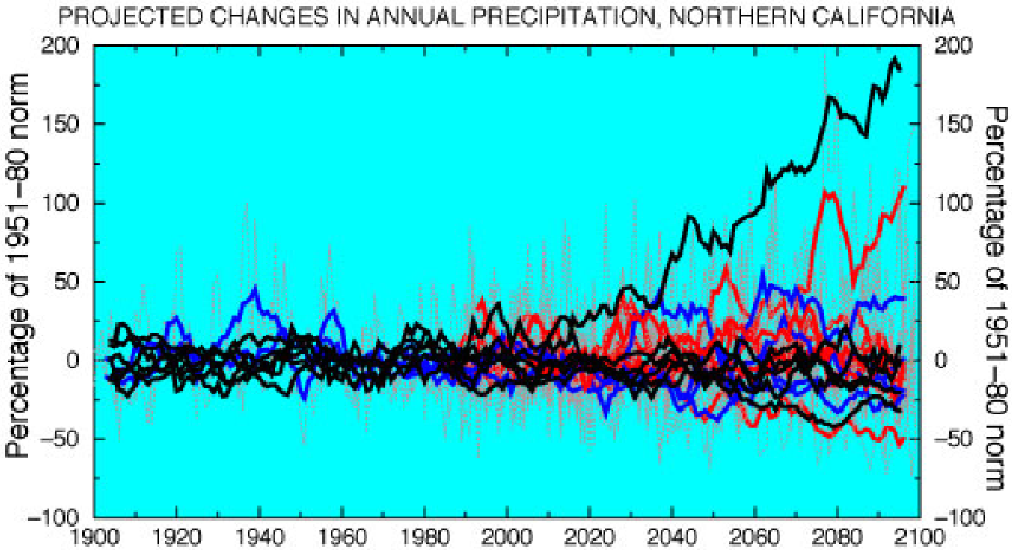



*Preliminary Results: Do not cite or reference.*

# Striking difference is in degree of consensus among projections of temperature and precipitation




Clearly warmer




Not certain about precipitation

# Aggregation Distorts Conception of Temperature Change

(Hayhoe et al PNAS 2004)

| | | | |
|---|---|---|---|
| HOW TO CHARACTERIZE THE CHANGE IN TEMPERATURE, 2070-2099, USING HADCM3 | | | |
| | | | |
| | | EMISSION SCENARIO** | |
| | | A1fi | B1 |
| | | | |
| Change in global average annual temperature | | 4.1 | 2 |
| | | | |
| Change in statewide average annual temperature in California* | | 5.8 | 3.3 |
| Change in statewide average winter temperature in California* | | 4 | 2.3 |
| Change in statewide average summer temperature in California* | | 8.3 | 4.6 |
| Change in LA/Sacramento average summer temperature | | ~10 | ~5 |
| | | | |
| *Change relative to 1990-1999. Units are ˚C | | | |

# Overview of Research Tasks

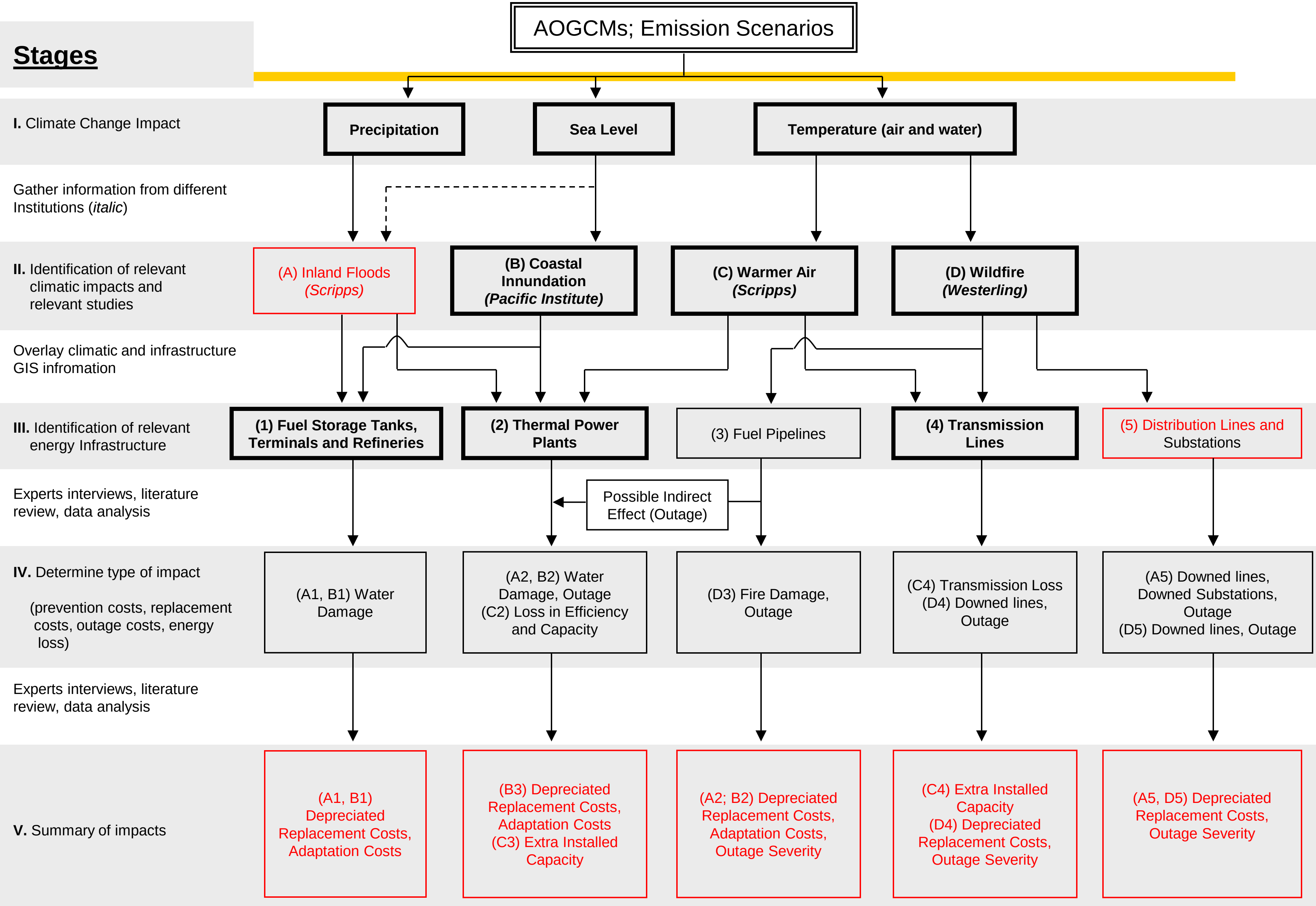
- Assess the vulnerability of …
  - *electricity infrastructure* to **warming temperatures**.
  - *electricity infrastructure* to **wildfires**.
  - *electricity, natural gas, and other energy infrastructure* to **sea level rise** and **extreme events**.

# Presentation Context:
# Parameter Impacts on Energy Demand and Supply

| Hydro-meteorological and/or climate parameter | Select energy uses |
|---|---|
| Air temperature | Turbine production efficiency, air source generation potential and output, demand (cooling/heating), demand simulation/modeling, solar PV panel efficiency |
| Rainfall | Hydro-generation potential and efficiency, biomass production, demand, demand simulation/modeling |
| Wind speed and/or direction | Wind generation potential and efficiency, demand, demand simulation/modeling |
| Cloudiness | Solar generation potential, demand, demand simulation/modeling |
| Snowfall and ice accretion | Power line maintenance, demand, demand simulation/modeling |
| Humidity | Demand, demand simulation/modeling |
| Short-wave radiation | Solar generation potential and output, output modeling, demand, demand simulation/modeling |
| River flow | Hydro-generation and potential, hydro-generation modeling (including dam control), power station cooling water demands |
| Coastal wave height and frequency, and statistics | Wave generation potential and output, generation modeling, off-shore infrastructure protection and design |
| Sub-surface soil temperatures | Ground source generation potential and output |
| Flood statistics | Raw material production and delivery, infrastructure protection and design, cooling water demands |
| Drought statistics | Hydro-generation output, demand |
| Storm statistics (includes strong winds, heavy rain, hail, lightning) | Infrastructure protection and design, demand surges |
| Sea level | Offshore operations, coastal energy infrastructure |



*Preliminary Results: Do not cite or reference.*



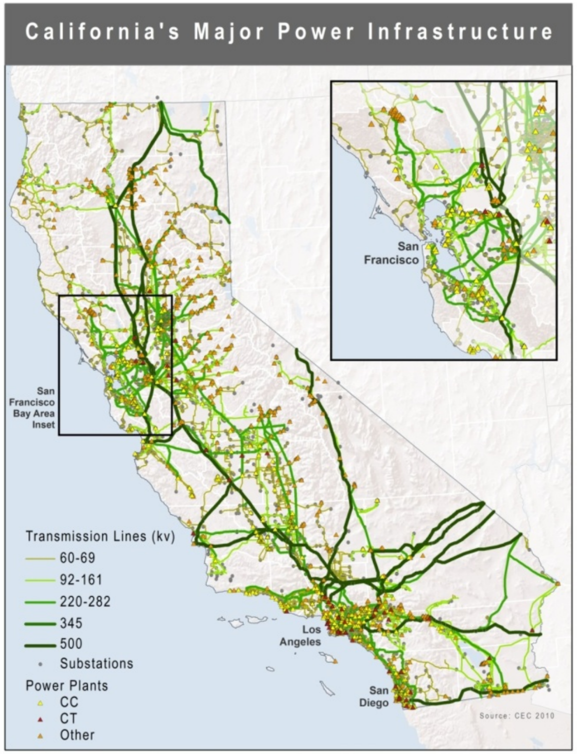


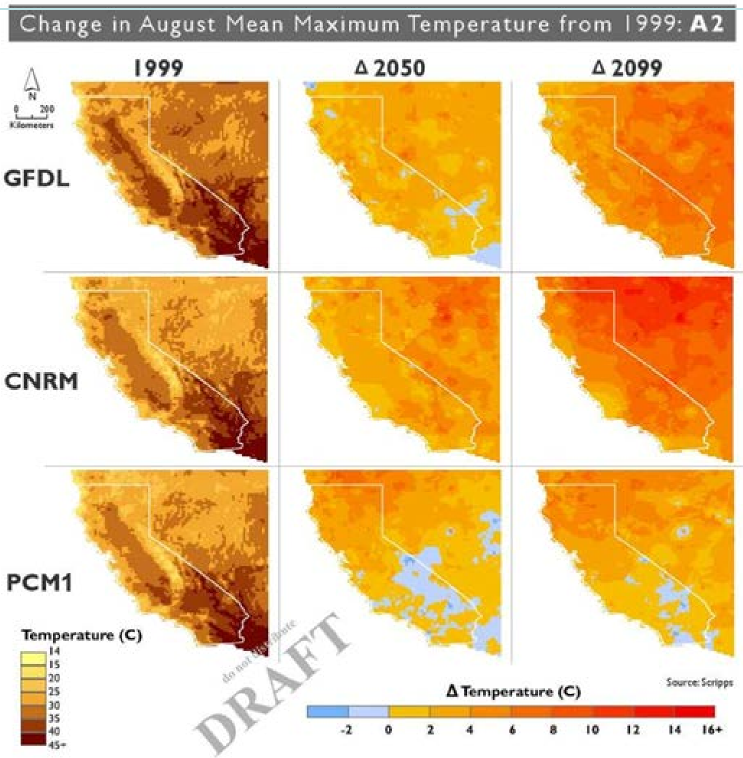

*Preliminary Results: Do not cite or reference.*

# Case Study: Risk to CA Energy Infrastructure

**BACKGROUND:**

- California Energy Commission funded study to estimate power demand and explore physical risk to CA energy supply system.
- Technical advisory committee, including power sector stakeholders, provide feedback on data sources and methods.
- Estimated risk for A2 and B1 scenarios for three time periods up to 2100




**BASIC METHOD:**

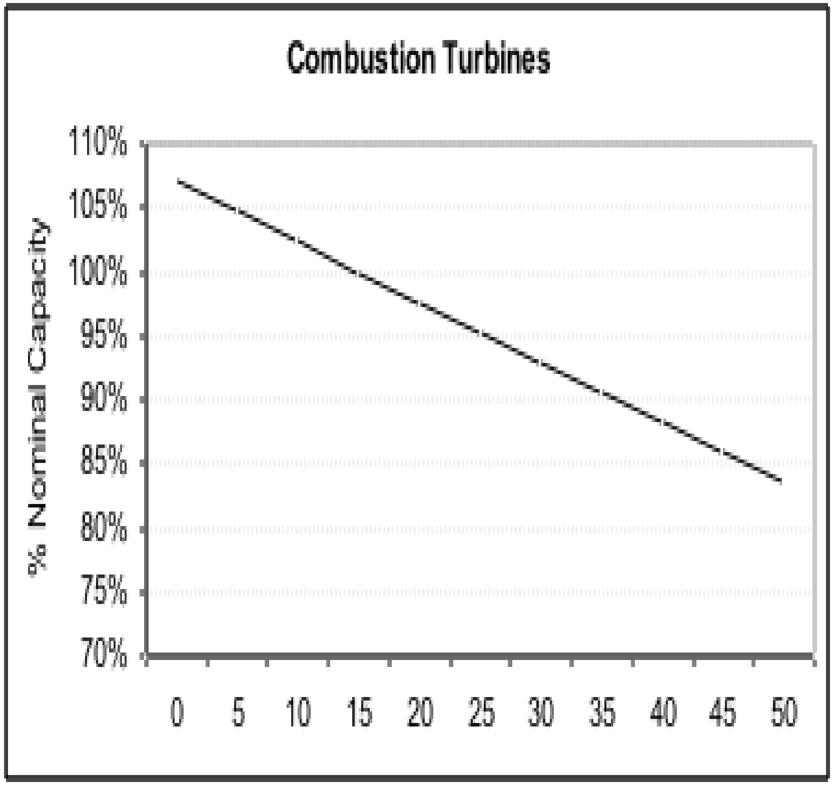
- Coupled downscaled AOGCM projections to electrical system thermal equations to estimate changes to system capacity and demand from increased ambient temperature.
- Overlaid sea-level rise estimates and wildfire projections with known location of CA energy infrastructure.

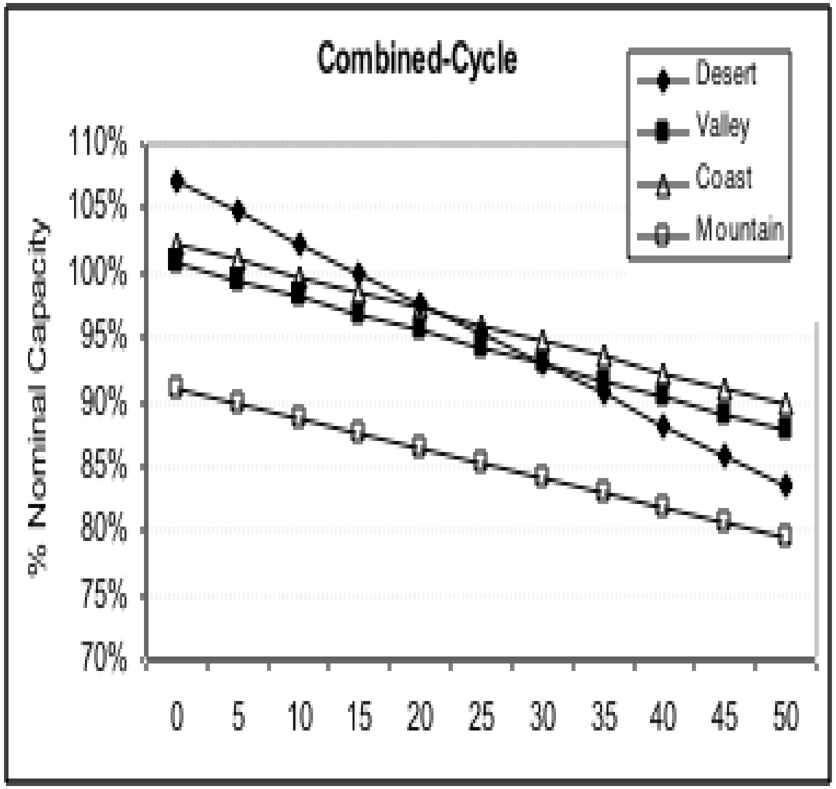


*s: Do not cite or reference.*

# Combustion Turbines and Combined-Cycle Power Plants

Change in Turbine Capacity as a Function of Ambient Temperature



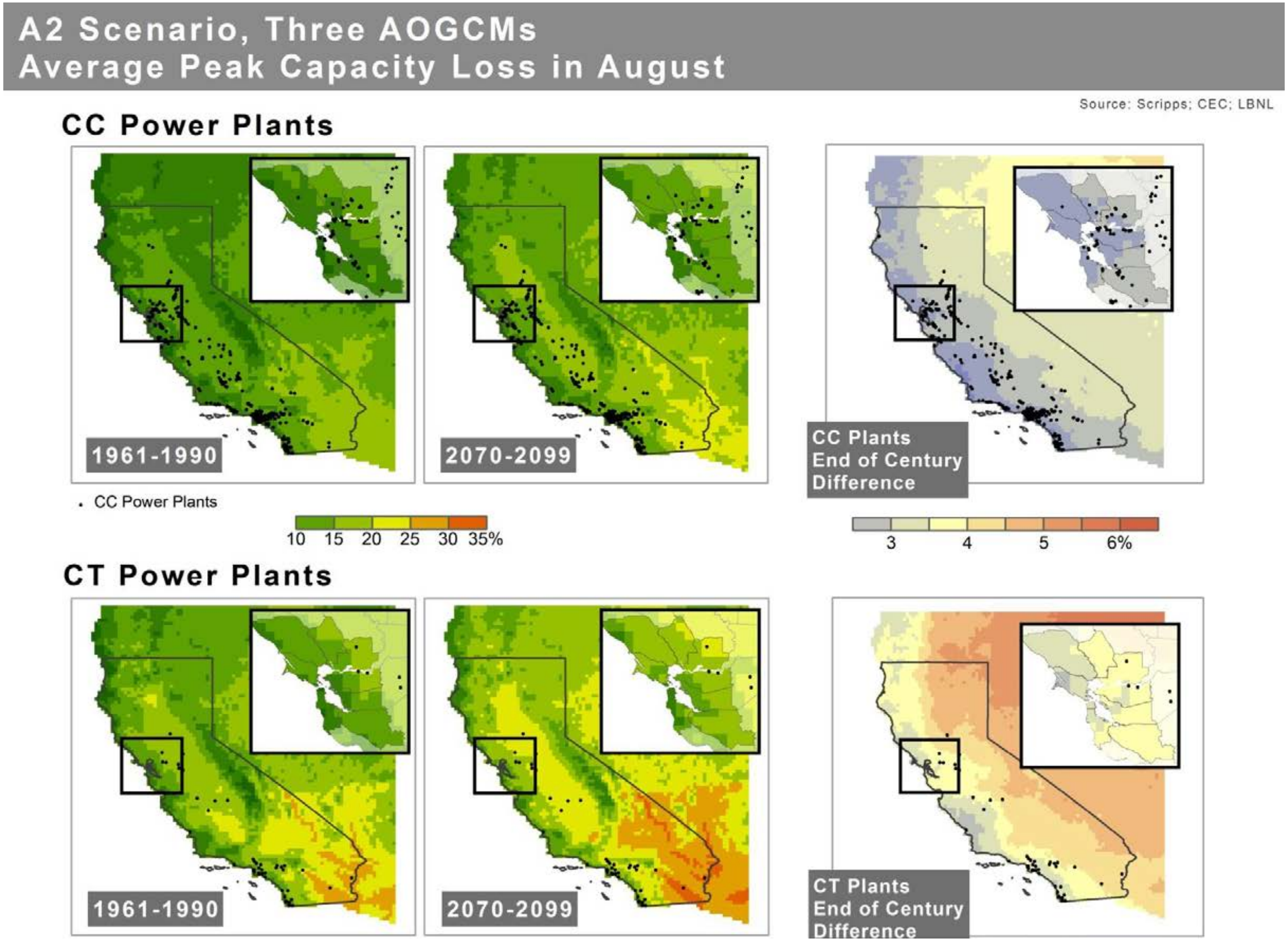




• Increased replacement of water to air cooling; air cooling is more sensitive to higher temperatures



*Preliminary Results: Do not cite or reference.*

# End-of-Century Impact Mapping

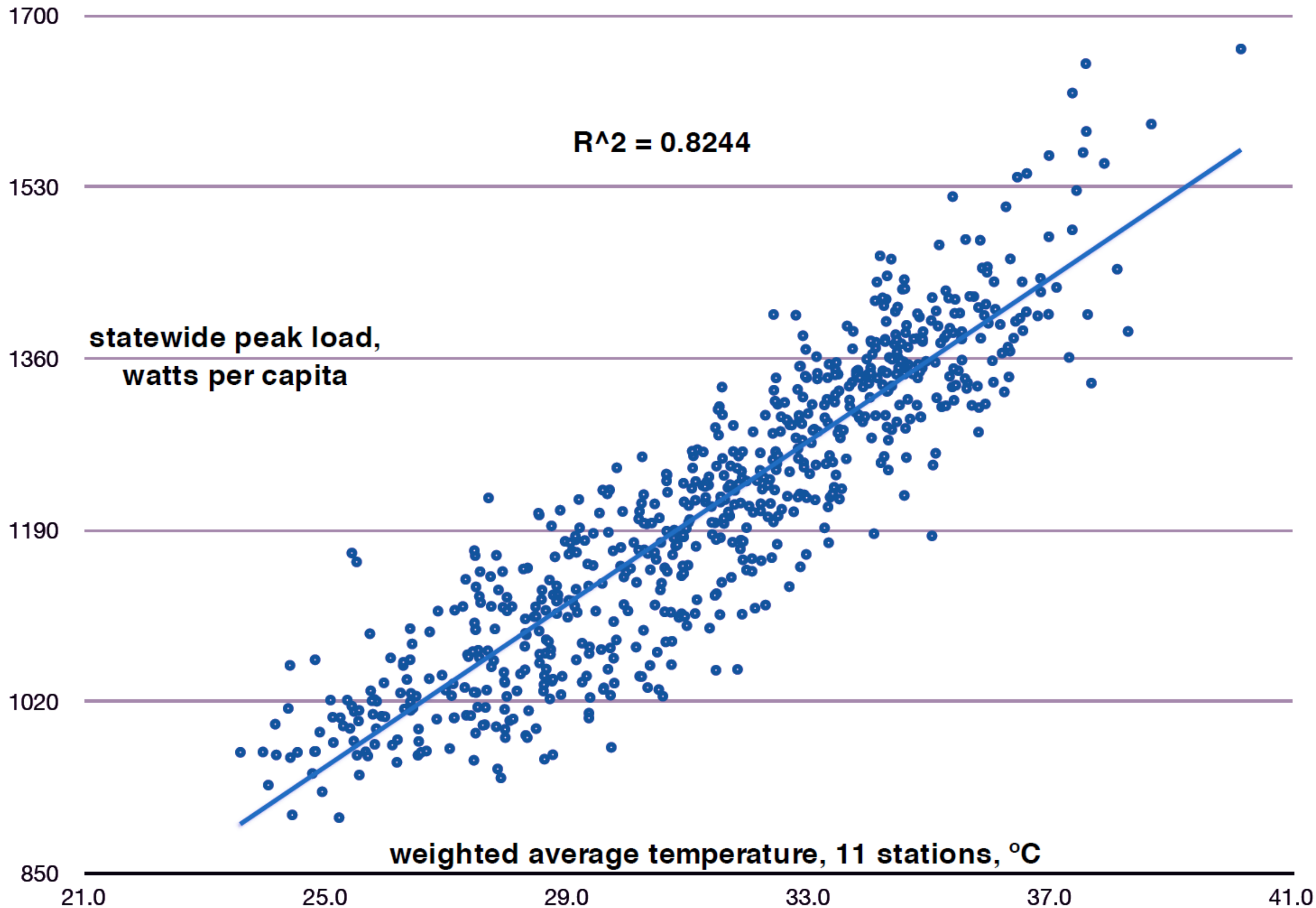



*Absolute Capacity Reductions* — *Incremental Reduction*



***Preliminary Results: Do not cite or reference.***

# Peak demand load vs. peak temperature



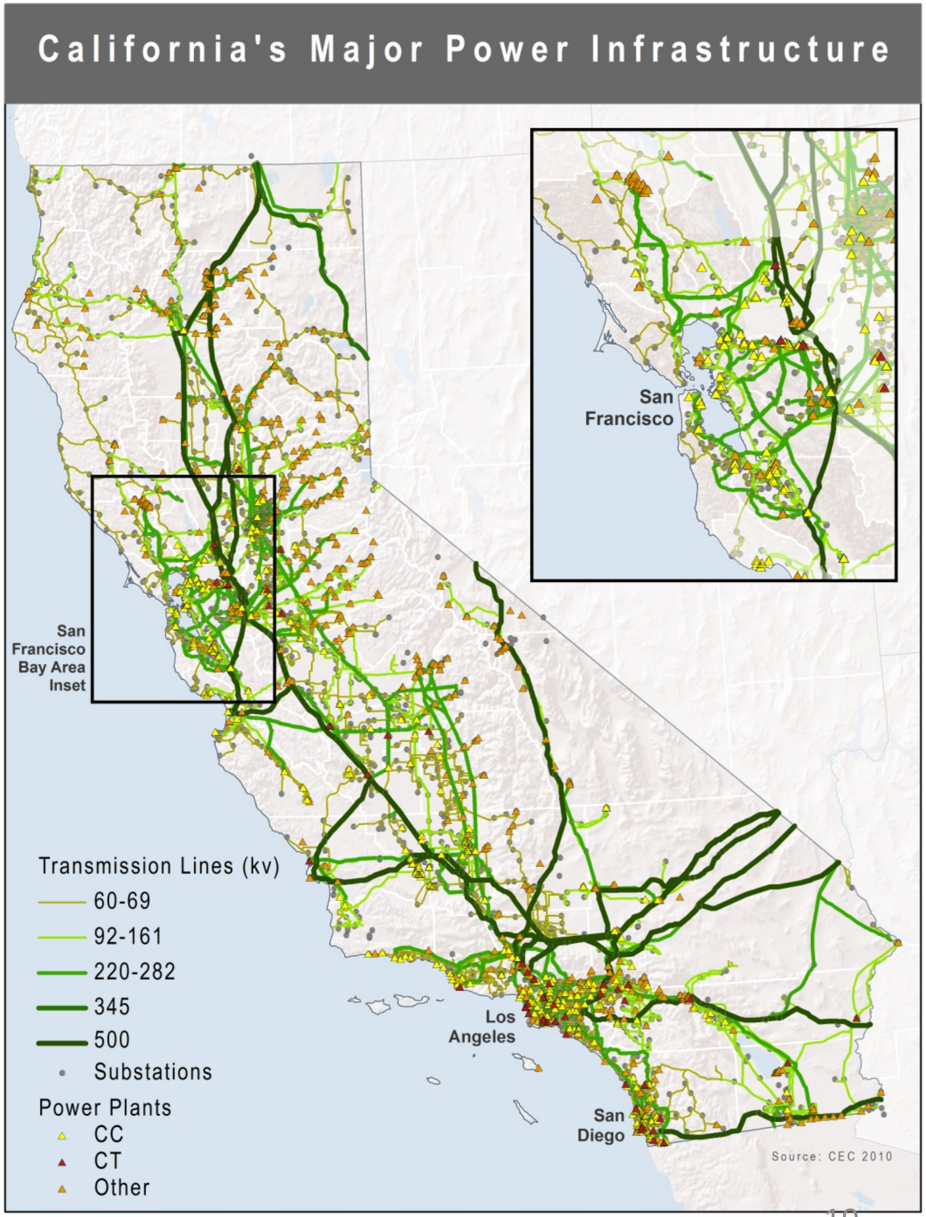



*Preliminary Results: Do not cite or reference.*

# Electricity Demand and Supply: Results Summary

- **Need for generation**
  - Peak Period Demand  Rise
    - 10 % - 21%
  - Peak Period Supply Loss (Natural gas plant)
    - 1% - 3.6%
    - 4% - 6.2% max
  - Transmission and Distribution Loss
    - up to 1% - 2%
  - Need perhaps 25% additional generation capacity

- **Need for transmission capacity**
  - Sub-stations
    - 2% to 3%  loss in capacity
  - Transmission lines
    - 7% - 8% loss of capacity
    - Limited data on sizes, locations, and usage capacity
  - Need perhaps 25 % additional transmission capacity

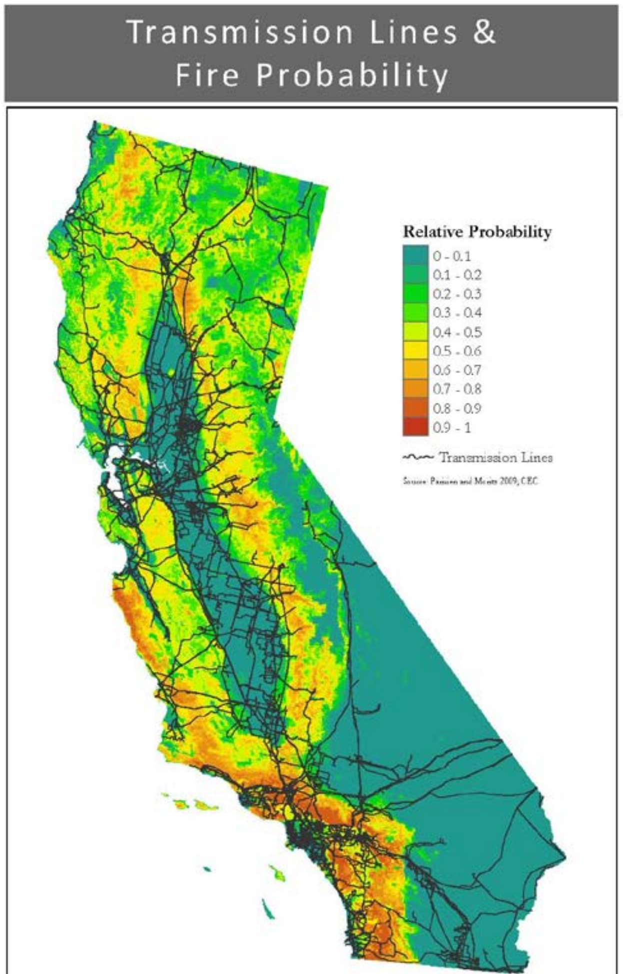




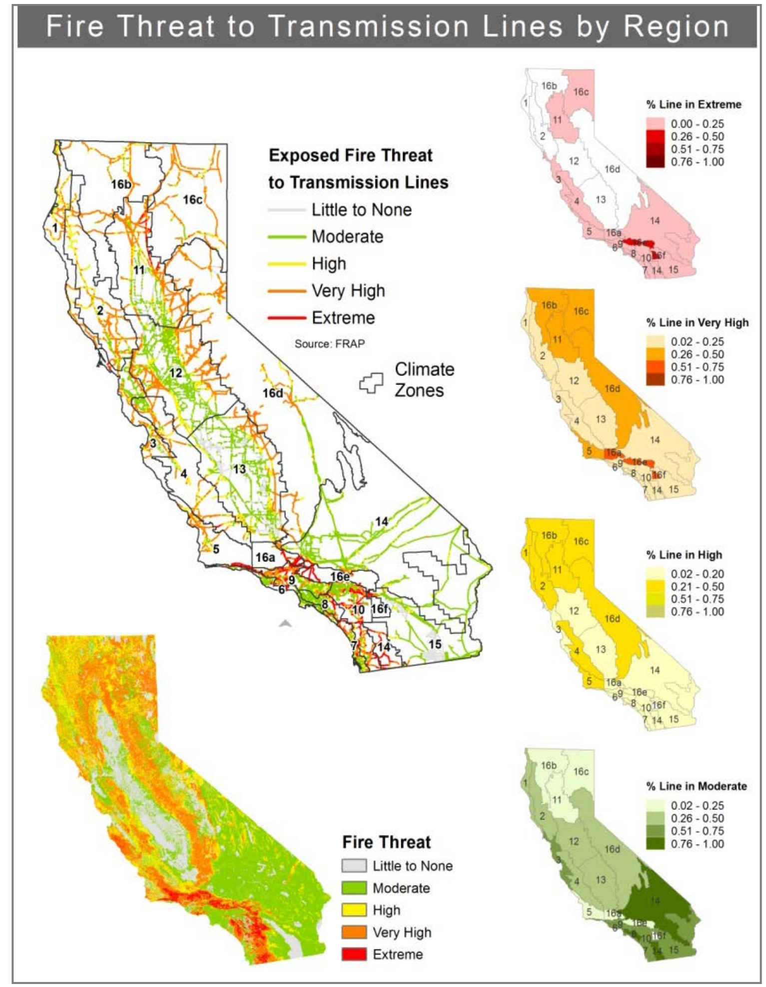

*Preliminary Results:  Do not cite or reference.*

# Spatial Models of Wildfire Risk

## models used for near-term projections




Parisien and Moritz, 2009

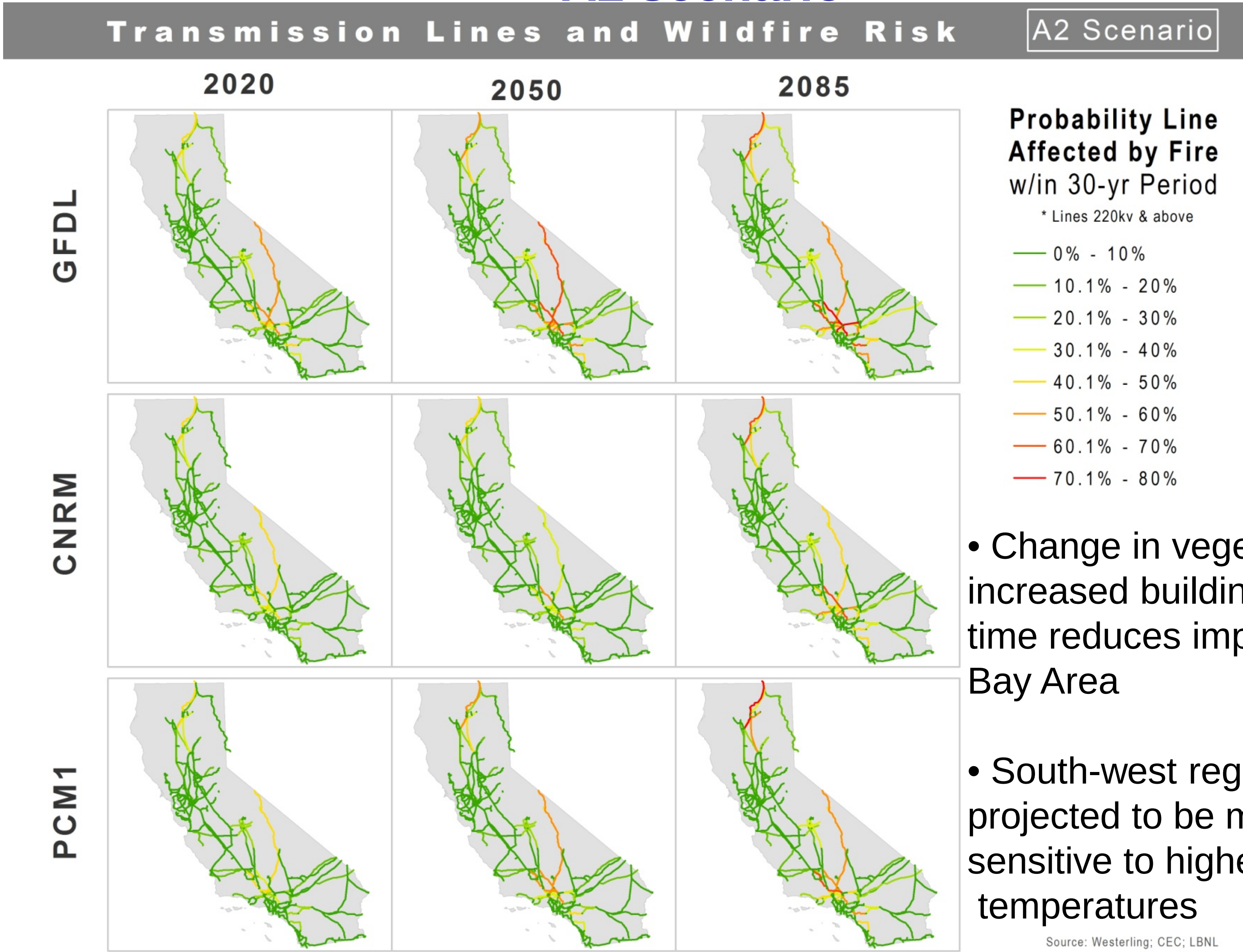



Fire and Resource Assessment Program (FRAP)



*Preliminary Results: Do not cite or reference.*

# Projected exposure of transmission lines to fire risk A2 scenario




- Change in vegetation and increased buildings over time reduces impact in south Bay Area

- South-west regions are projected to be more sensitive to higher temperatures

Source: Westerling; CEC; LBNL

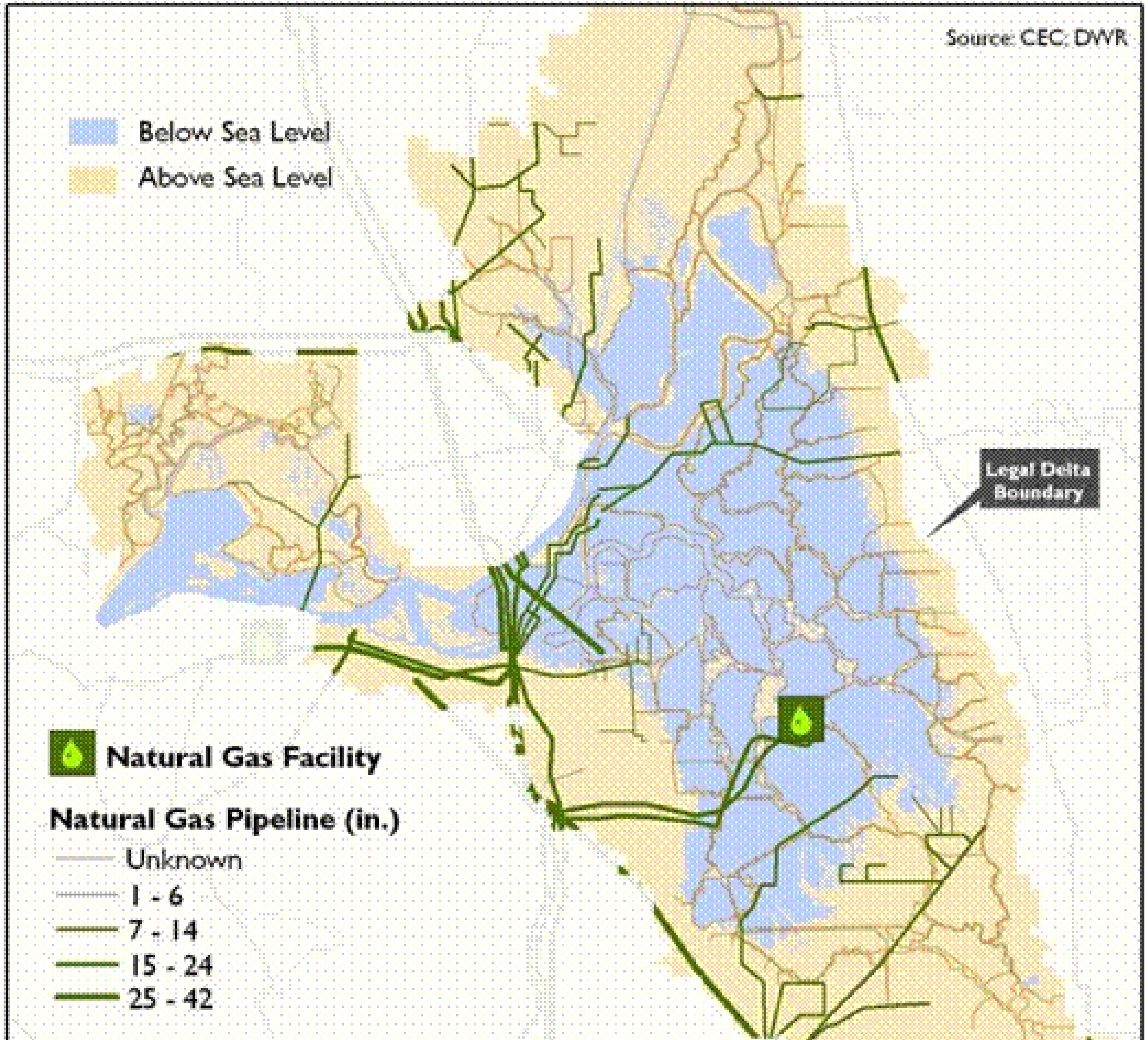


*Preliminary Results: Do not cite or reference.*

# Wildfire Impacts

- The study finds that key transmission corridors can be vulnerable to increased fire frequency.
- It found a 40% increased probability of wildfire exposure for some major transmission lines, including the transmission line bringing hydropower generation from the Pacific Northwest during peak demand periods.

# Natural Gas Infrastructure Below Sea Level

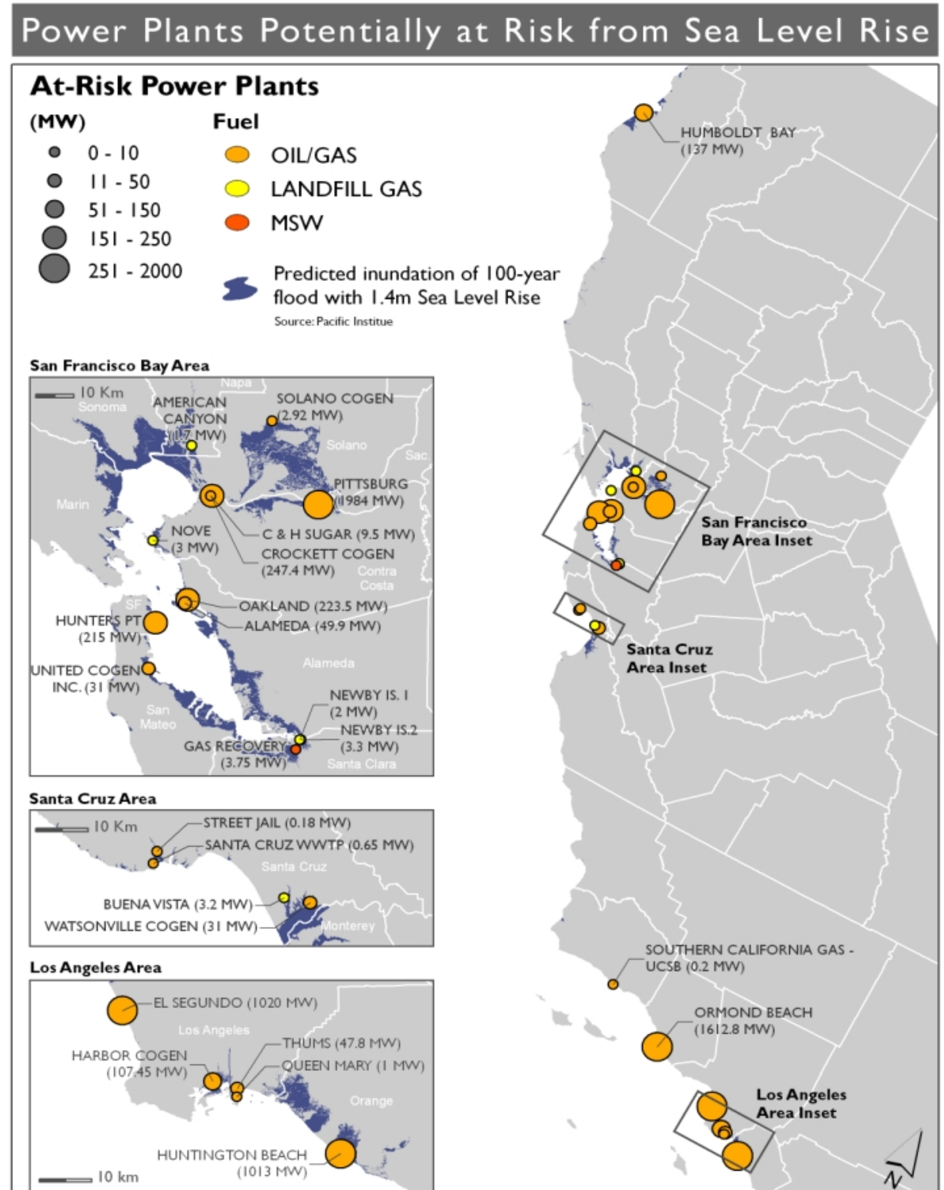





*Preliminary Results: Do not cite or reference.*

# Sea Level Rise Impact Mapping & Comparisons

- Projected sea level rise – 1.4 meters
- 25 power plants and about 90 substations are vulnerable to sea level rise
- Humboldt Bay and Antioch Site visits indicated that coarse vertical resolution of CA topography may have over- or under-stated impacts in power plant locations.






*Preliminary Results: Do not cite or reference.*

# Lessons Learned

- Temperature impact on demand is much higher than on supply infrastructure
  - Impact on hydropower supply may increase or decrease generation depending on water supply conditions
- Impact of wildfires could potentially be high
- More data and research are needed to evaluate wildfire and sea level rise impacts on the power sector infrastructure and temperature impacts on electricity transmission and distribution

# Published California Articles


1. *Sathaye, J.A., Dale, L.L., Larsen, P., Fitts, G., Koy, K., Lewis, S., Lucena, A.F.P., 2012. Estimating Risk to California Energy Infrastructure from Projected Climate Change.* California Energy Commission. Publication number*: CEC-500-2012-057.*

*2. Sathaye, J., L. Dale, P. Larsen, G. Fitts, S. Lewis, K. Koy and A. Lucena. (2013).* Estimating impacts of warming temperatures on California's electricity system*, Global Environmental Change* 23 (2013), pp. 499-511

*3.* Sathaye, J., L. Dale, P. Larsen, G. Fitts, S. Lewis, K. Koy and A. Lucena. (2013). Assessing the risk to California energy infrastructure from projected climate change. *IEEE Power & Energy Magazine,* May 10.1109/MPE.2013.2245582

# Acknowledgements for CA Research

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***Preliminary Results: Do not cite or reference.***